THE PERISTALTIC-LIKE NATURE OF ORGANIC RESPONSES

By P. F. SWINDLE, University of Missouri

A INTRODUCTIION

The expression *peristalsis* is traditionally applied to the wave-like movements of the intestines. When a living intestine, e. g., the small intestine, is stimulated at a certain point, one observes first a wave of relaxation and following it a wave of constriction. Normally, this double wave travels along the intestine in a particular direction. It passes from the duodenal toward the caecal end. This peristaltic movement may be looked upon as a response of long duration, the greater part of which is a positive after-effect of the stimulus or force which conditioned the initial portion of the response. For the execution of each portion of the peristaltic response, organic structures function which are not directly involved in the execution of any other part of the response; new sets of structures come into play one after another until the entire intestine has reacted. One set of structures functions, conditions action in the neighboring structures which have not reacted immediately before, and then undergoes a recuperation pause before it functions normally again. If one stimulates the intestine a short distance behind a peristaltic wave, one can thereby produce a response at that point but this stimulation ordinarily does not give rise to a peristaltic wave; instead, ordinarily occur only the well-known churning movements which usually take place about a bolus that continually stimulates the intestinal wall.

Peristalsis is also characteristic of the vascular system. In the frog or turtle, the contraction appears to start in the sinus venosus and to travel from there in a definite direction to more distant portions of the system. Peristalsis in the insect heart has a much greater resemblance to that of the intestine.

Peristaltic-like movements of the lungs of certain animals, e. g., of the frog, are easily observed. If one stimulates the end of a half-inflated frog lung, a characteristic wave of peristalsis will pass from the point of stimulation to the other end of the lung.

The points of special interest derived from a study of the above mentioned structures are:

1. Different organic structures are involved in the execution of different portions of the responses of long duration.
2. One set of structures conditions action in neighboring structures which have undergone a recuperation pause.
3. The peristaltic response can be started at any point along the intestine. If a point midway between the duodenum and ileocaecal valve is stimulated, the response originates and progresses from the mid-point to the caecal end only.
4. Muscular structures can function for a considerable time without pause, as is illustrated by the churning movements which can be induced behind the peristaltic wave. In view of the circumstances that non-recuperated muscular structures can execute such pronounced movements, would seem to indicate that the nervous system of the intestine, perhaps the plexus of Auerbach is necessary for the transmission of the peristaltic wave and that after a given portion of this plexus reacts it can function normally again only provided that an adequate recuperation pause intervenes.

If it were the case that nerve fibers, which we could call a, b, c, d, e, f, etc., left the intestine at intervals of one centimeter and terminated in such a bodily appendage as the arm, we should expect a movement of the hand to occur as often as the peristaltic wave passed over these points. If this were the case, we could name the movements of the arm a, b, c, d, e, f, etc. Moreover we should expect that if a particular, extra activity were associated with c, a similar one with f, etc., the hand would beat a 3-rhythm. The extra responses would cause the c- and f- responses to be different from the others, e. g., b and d.

My attempt in this paper will be to show that the theoretical nervous and muscular mechanism of the above paragraph is in a high degree similar to nerve-muscle complexes in general. I shall deal with the unavoidable conclusion that a nervous structure which functions and conditions a muscular movement does not do exactly the same thing again before the occurrence of an adequate recuperation pause, not for the muscular but for the nervous structure; instead we must conclude that the nervous response, besides conditioning the muscular movement, conditions also a response in adjoining nervous structures which in turn excite a similar movement of the muscles, and so on.

The assumption of such nerve-muscle mechanisms seems to be a necessary prerequisite for explaining the existence

and behavior of the unitary group which I have discussed at considerable length in some of my previous articles.[1] The assumption of peristalsis in the nervous system should enable us to realize it is significant after all that animals ordinarily possess millions of nerve fibres which our systems of thinking have heretofore not required as necessary for ordinary forms of behavior. In other words, our assumption furnishes a possibility of using for theory an entire complex nervous system.

B THE UNITARY GROUP A FRAGMENT OF A LONGER DISCONTINUOUS RESPONSE

The unitary group may be defined as *a number of qualitatively very similar movements which are innately associated and which accordingly induce or condition one another in the particular temporal order in which they occur.* The elements of the group are qualitatively very similar because they are approximately the same in complexity, in direction, and in amplitude of movement—in short, they are qualitatively very similar if any one of them seems to be a facsimile of any other element of the group.[2] For an illustration, I selected the group of Fig. 1 because, in spite of the circumstance that the amplitudes of movement vary in this exceptional case, the direction and apparent complexity of the five elements are nevertheless so nearly the same that they seem to belong together as a unified whole. The groups of Figs. 2, 3, and 4, also are characteristic unitary groups.

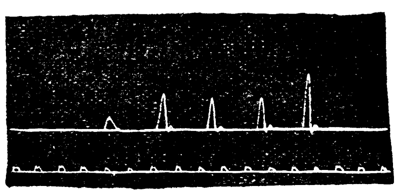

FIG. I

Fig. 1 is a group of innately associated elements which a cockatoo produced by striking a tambour with its beak. The animal was not trained to produce these simple movements in

[1] Ueber einfache Bewegungsinstinkte und deren kuenstliche Beeinflussing, *Zeit. f. Sinnesphysiol.,* 1915; Mechanische Rhythmem bei dem Menschen, *Zeit. f. Sinnesphysiol.,* 1916; The Term Reaction Time Redefined, *Amer Jour. Psychol.,* 1916; Visual, Cutaneous, and Kinaesthetic Ghosts, *Amer. Jour. Psychol.,* 1917.

[2] In the case of the group which contains only a single element, this can of course not be said.

this particular order. For this reason, the series may be called an 'instinct-group;' and further, because it contains five elements, it may be conveniently called a '5-instinct-group' or simply a '5-instinct.' While the amplitude of movement of a group is generally quite constant, it is nevertheless more variable than either the tempo or the direction of movement and is accordingly the least significant criterion of the unitariness of the group; for it seems that no animal is capable of performing a series of movements of absolutely equal amplitudes. The amplitude is in any case more easily influenced than either the tempo or the direction of movement. The problem of the cause of these variations in amplitude of the movements within a given unitary group is identical with that of the cause of the final accent which will be thoroughly discussed in this paper.

The unitary group of Fig. 1 maintained its identity in different environments because, in general, its first element conditioned the second; the second, the third; the third, the fourth; and the fourth, the fifth element. In other words, it can be said that *it maintained its identiy in the different environments because it occurred more frequently as a whole than as fragments of the whole.* The group, as a whole, occurred more frequently than one or all of its parts without the whole because the adequate stimuli for the initial element occurred more frequently than did all those for the other four elements of the group.

Relationship between instinct and habit: A given group can occur more frequently as a whole, thus maintaining its identity when the animal is subjected to different environments, if especially the initial element is associated with the various other responses which condition it every time *they* occur. When this state of affair exists, however, the series is not only an instinct-group but also a 'habit-group;' *a habit-group is only an instinct group which occurs as a whole more frequently than originally.* The process of converting an instinct-group into a habit-group is a process of training. It may sound paradoxical that an instinct-group must be made habitual before it can be treated as a unitary group to which a particular quantitative expression is applicable; but, as was previously suggested, the training merely causes the innately associated series, that already exists, to occur more frequently as a whole than as possible parts. Fig. 2 will serve to make this point clear. The cocktoo produced these groups also by striking the tambour with its beak.

These two unitary 5-groups were associated in such an

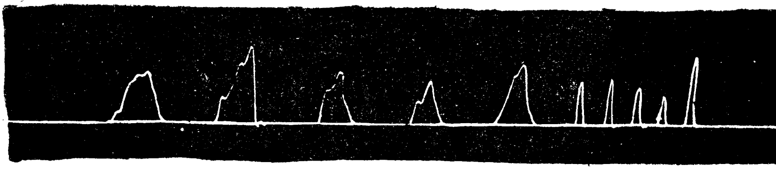

FIG. 2

order that the final element of the first conditioned regularly the initial element of the second group. Both of these were instinct-groups, and *both were at the same time habit-groups,* otherwise neither of them would have maintained its identity in the different environmental conditions as both of these really did. The second group was, however, more habitual than the first, because its initial element occurred now whenever the final element of the first group occurred to condition it; *the second group occurred more frequently than the first, because the first group was the cause of the second and the second group was never the cause of the first one.*

Fig. 3 is essentially the same as Fig. 2, even though it may seem at first sight, as though we were concerned with a 5- and a 6-group instead of two 5-groups as in Fig . 2. The second group of this figure is not the first one repeated with

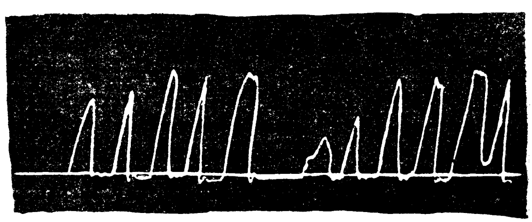

FIG. 3

slight modifications; groups which are of as short duration as these, do not recur until a pause of several seconds elapses. Observations show that a group of very long duration may recur without the intervention of a long pause; as a rule, the longer the group the sooner it can recur after the final element is executed. This can only mean that the structure correlates of the initial elements of the long group become recuperated while the succeeding elements are being executed.

The final accent: It may be noticed that the final element of the first group of Fig. 3 is more elaborate than any other

element of the same group — in short, it expresses a greater expenditure of muscular energy than does any other element of the group. The final element of the second group is still more elaborate; and in this case, it is easily analyzed into at least two distinct movements. It consists of the usual stroke of the beak against the tambour followed by an unusual stroke with one side of the beak, the latter being responsible in the kymograph record for the distinct appendage of the fifth element. The fifth element plus this appendage constitutes the *final accent* of the 5-group. Without this extra appendage, the fifth element is, like that of the first 5-group, accentuated—the word accentuation implying that the element in question is a compound consisting of two or more different activities—however brief these may be. The final element of the second 5-group is, because of the extra stroke, more complex than the final element of the first 5-group, except when we have special reasons for considering the second 5-group as a constituent response of the final accent of the first group.

Elements of the unitary group associated in one direction only: It is a fact of considerable significance that the elements are associated in a definite direction. When the first element occurs it conditions the second, the second conditions the third, and so forth until the fifth element of a 5-group is executed; but, when the fifth element is the first to occur, it does not condition any other element of the group. Also, for example, when the second element occurs first, it conditions the third and not the first element of the group. The association of the elements in a single direction is a fact which can be demonstrated very clearly and easily by the proper use of 'discrimination activities.' For instance, just as a cockatoo was executing a certain element of a group, I stimulated it in such a way that it uttered a brief cry at the same time; and, while it was executing the next element of the same group, I presented the appropriate stimulus to cause it to shake its head slightly. These brief extra activities of crying and shaking the head became associated with the two respective elements of the group and were regularly conditioned by them in the same order in which they were caused to occur in the training. The element which conditioned the shake of the head, occasionally occurred without being preceded by that one which the training caused to condition the crying; but, when the other element was produced first, it was regularly followed by the second one which could be identified by the extra or discrimination activity associated with it. Another demonstration of the association of the elements of a group in one

direction only, is the fact that the second of the two associated groups of either Fig. 2 or 3 sometimes occurred alone while the first group was in either case regularly succeeded by the second one. In each of the cases mentioned, the second 5-group is a discrimination activity, the first element of which is associated with and conditioned by the final element of the first 5-group.

Different organic structures are involved in the execution of the different elements: The fact that an activity, such as that of the crying of the cockatoo, is conditioned by a given element and not by any other one of the group, is a logical demonstration that the various elements are behavior correlates of organic structures which are in no two cases exactly identical; in other words, it is evidently not the case that the entire set[2] of organic structures, which is directly responsible for the initial element of the group, functions repeatedly to produce each of the succeeding elements. With that set which is involved in the execution of the element with which the activity of crying is associated, one or more organic structures are present which are not found in a set involved in the execution of any other element of the group; otherwise, the act of crying would be conditioned also by other elements of that group. The structure correlates of the activity of crying are associated with some of those particular structures which do not function in the execution of the other elements If the elements of a 5-group are merely the initial one repeated four times, the crying would be necessarily conditioned by all the perceptible elements of the group instead of by the very particular one with which the crying was associated in the training.

The unitary group is a fragment of a longer series of innately associated elements — The complete instinct: My observations and experiments on trained and untrained organisms have led me to conclude that each unitary group is only a fragment of a quantitatively larger series of innately associated elements. It is a fragment which is either completely or incompletely isolated from the innate series of a larger number of elements which present a progressive qualitative change from the initial to the final one — *such a series is a complete instinct, and any fragment of it is an instinct-group.* Whenever the initial element occurs, the series runs its natural

[2] The term 'set,' as here used, merely signifies that many nervous and muscular structures are involved in the execution of a single element of the group.

or innately determined course, unless the organism is in the meantime acted upon by an external or internal[3] stimulus or force which conditions a response that completely interrupts the series in question. Since the qualitative change is a gradual one, any relatively short discontinuous fragment of the series is a group of qualitatively very similar elements.

The response which occurs at the point of interruption of the instinct becomes associated with the final elements of the totally or partially isolated group. If, while a member of the body is performing a series of innately associated movements, sufficient physical strength is exerted—for example, by another person's grasping and holding the beating member—to interrupt this series just after the fifth element is executed, a unitary fragment or a unitary 5-group is isolated from the series. If the interrupting force occurs frequently at this point and each time calls forth a response which would otherwise not accompany any element of the series, a unitary group of muscular responses becomes accordingly established as an independent response. What is more, the very force *that causes the complete isolation of the 5-group, gives rise to the extra muscular response which becomes associated with and is later conditioned by the fifth element.* The extra response may, however be of such short duration and of such a nature qualitatiyely that it does not inhibit the remaining part of the series, under which circumstance a unitary 5-group is established without being permanently dissociated or isolated from the series. When such extra acts are caused to occur at regular intervals, the series merely becomes rhythmized.

The forces which call forth the extra activities, need not act directly on the beating member; they may act upon it in an indirect way by affecting first the nervous structures which, in the strict sense of the word, *condition* these extra muscular movements. This is what more generally takes place. Whatever the nature of the interrupting forces may be, which are applied to the organism while the series is in progress, the essential thing is that at each of the presentations one or a number of activities are called forth and complicate an element of the series.

The foregoing observations and experiments of this article justify the following statement which may be used as a principle in interpreting modified responses. *Any one of the extra muscular responses which is responsible for the accentuation of a movement or which is merely conditioned regularly by*

[3] An internal stimulus might be a hormone. See discussion on p. 208.

the final element of a group is either a consequence of the force which directly or indirectly interrupted the series of innately associated elements, or it is the very response which caused that force to be applied to the already acting organism. This principle is applicable to all cases of unitary groups, whether or not the groups in question have been completely isolated from the longer series. It means the same thing to say it is applicable to all cases of final accents or concluding responses, independently of whether these are of short or long duration.

If the extra activities are brief ones which occur in the training immediately after the fifth elements and before the succeeding elements of the original response are executed, these extra movements will form in the kymograph record, appendages comparable in each case to that one which immediately follows the fifth element of the second group of Fig. 3. An examination of ordinary human activities does not enable us to understand why the bilaterally symmetrical human being should beat so frequently the 3-rhythm, unless we find or suppose that such extra movements regularly occur to give to each real 2-group of some of the 2-rhythms, which are developed in ordinary life, the appearance of containing three elements. If, however, the extra movements should be caused in the training to occur simultaneously with every second element of the series, the groups should later not be overestimated by a single element; there would be developed real 2- instead of pseudo-3-groups.

Fig. 4 is an illustration of a large part of a complete instinct in which many incompletely isolated groups are manifest.

The original record from which this figure was taken is 62.5 cm. in length. The chronoscopic markings below the movements occured in the tempo of 0.2 sec. The entire series of movements of which five parts are here given, endured 6 min. 17.8 sec. This is approximately the time which elapsed between the execution of the first movement in the lower left hand corner and the last one in the upper right hand corner. In examining the movements, one should begin with the lowest of the four rows and read from left to right. When the test was made, the subject merely knew that the finger was moving against a tambour.

The qualitative change manifested in Fig. 4 is a progressive change of tempo. Another series may show only a change of amplitude, a change of direction, or a change of tempo, direction, and amplitude of movement. As was previously stated, it seems to be impossible for an organism to produce a succession of beats of equal amplitudes; there is always at least a slight variation from movement to movement. Some

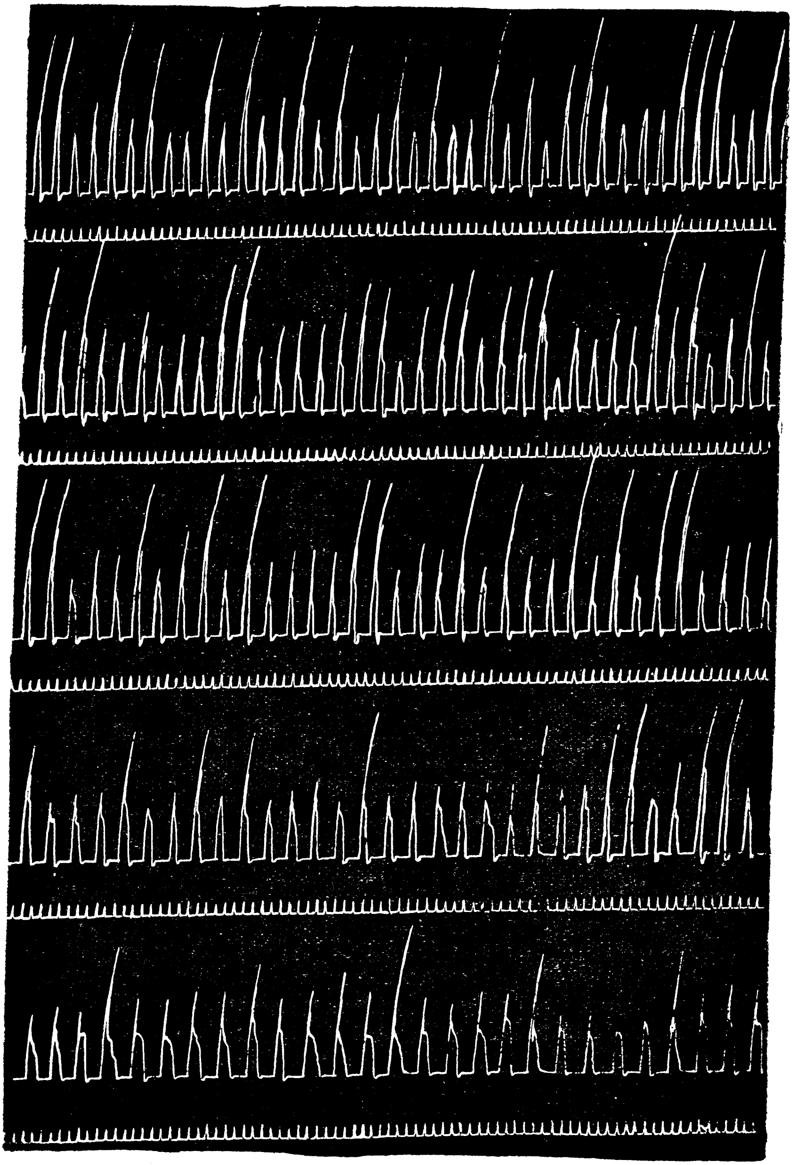

FIG. 4

of the movements of this series indicate a greater expenditure of muscular energy than do others; and it is of interest here that each of these was made strong by a very special training. Any one of the accentuated elements represents an extra amount of muscular energy simply because the training served to compound it and at the same time leave its neighboring elements relatively simple. Each accent consists of a number of activities, viz., the original element of the series plus one or more extra activities, any one of which is analogous to the cry or the head movement of the cockatoo, that served to modify a certain element of the group, as was discussed on page 192.

The art of reading kymograph records is difficult to learn; but this particular record is so simple that no one should encounter any special difficulty in attempting to follow the 5-rhythm through the series. The most essential caution which I can give the reader, who wishes to trace a particular rhythm in the record, is that he must learn to pay attention to final accents and not to look for initial or intermediate ones; what may at any time seem to be the initial or intermediate accents are the final accents of groups of other rhythms and should be accordingly overlooked while any particular rhythm is being traced. One must also bear in mind that if any errors occur in the production of the rhythm, these are seldom under-estimations but are almost invariably over-estimations of the group by a single element. It should be noted, however, that these are only apparent over-estimations; for what really happens is that a final accent of a group is at such times easily analyzed into two distinct movements, as is true of the final accent of the second 5-group of Fig. 3. When one takes note of the precautions here stated and reads from left below to right above, beginning anew at each of the five rows of movements, one easily finds that every fifth element of the series is accentuated; one who observes this, observes that which may be called a psychological 5-rhythm in the series.

After the 5-rythm has been traced, one might trace also the 7-rhythm which started later in the series. It is present first in the second row of movements from the bottom; and it should be no more difficult to find it than it was to re-discover the 5-rhythm in the same row. After this second task is accomplished, the 11-rhythm, which is present first in the third row of movements, may be traced. If these three attempts at tracing rhythms do not involve all the accentuated movements, it is advisable to try to detect still another rhythm. But, if no other one, whose groups are numerically different

from any of those already discovered, can be traced, it is well to search for a second 5-, 7-, or 11-rhythm, the accents of which are not in all cases coincident with those of any one or all of the rhythms already traced. Two non-coincident 7-rhythms are present in the fourth row, and two non-coincident 5-rhythms are to be found in the upper row of movements. It is easily observed that with the increase in tempo the accentuated movements become more numerous, which fact is due to the circumstance that not all the rhythms started simultaneously but at different points of the series. This particular series of movements does not happen to contain a second 11-rhythm.

In my many pounds of kymograph records of the movements of trained animals and human beings, it is unmistakably the case that many of the learned rhythms are sometimes duplicated and even tripled in the same series. This was the case even though the training was at no time purposely designed to produce this result. This fact shows that a training which causes an organism to beat with a given bodily member one rhythm of a particular numerical value, trains it at the same time to beat with the same member other rhythms of the same numerical value.[5] Sometimes only one of these occurs alone, while at the same time two or more of them occur in a temporally superimposed order, in which case their accents may or may not be coincident. Of course if all of the rhythms of a certain numerical value should occur simultaneously and accordingly have their accents coincident, the analysis of the amalgamation of activities would be so difficult that in reading the kymograph record we should generally recognize only a single rhythm. By introducing discrimination activities, however, such as the crying or the extra head movement of the cockatoo, and associating these with appropriate elements of two 5-rhythms, for example, which can be caused to occur simultaneously both of these rhythms can be detected in the series where otherwise only one may be judged to be present. This experiment is possible only because either one of the two rhythms, which may occur together, occasionally occur separately. When they occur separately, the two qualitatively different discrimination movements can be associated with two numerically corresponding elements; and, after the associations are established, the person, who is well acquainted with the activities of the organism in question, can present the appropriate stimuli to cause both of the rhythms to start simultaneously. In this case, the two discrimination acts occur

[5] When the unitary groups of two or more rhythms are numerically the same, I shall speak of the rhythms as numerically identical ones.

together and thus furnish conclusive evidence of the presence of the two rhythms.

Apparent transference of ability: We have seen that *a training which causes an organism to beat with a given bodily member a rhythm of a particular numerical value, trains it at the same time to beat with the same member, simultaneously or at different times, other rhythms of the same numerical value.* It is also the case that *when the training is designed to teach the organism to beat a particular rhythm with a given bodily member, all other members are at the same time trained to do numerically the same thing.* A human being who is trained to beat with his foot the 5-rhythm, for example, is later capable of beating one of the same numerical value with his head or hand. A cockatoo which was trained to beat a 5-rhythm with its head, frequently beat a 5-rhythm with its foot, which it moved back and forth past its beak.

I have records of many such transferences. These are, however, only *apparent* and not *real* transferences; *for the training is generally not limited to a single member, but involves the entire body.* It is really not correct to say one particular member is beating alone merely because it is striking something or only moving in the air; for the entire body is active in numerically the same way at the same time. It may be at one time the hand, at another time the head, or at another the foot which is the most active; but it seems that whenever one of these members is making strong movements, the others are also active in numerically the same way, even though perhaps very much subordinated. Anything that occurs to alter one or more elements of the series which the hand is producing, also alters a temporally corresponding element of the simultaneously produced series of the foot or head. To generalize, *any stimulus which affects the organism while a series of one bodily member is in progress, and calls forth a response which becomes associated with an element of this series, generally calls forth a similar response which becomes associated with and thus causes corresponding elements of the other bodily members to be also accentuated.* And *what is true of the complex organism is true of any complex portion of it, such as the hand, foot, or head.*

The unitary group consists of a pattern of allied responses: One important reason for entering here into the discussion of certain facts of rhythm production, is to show that any element of a series is generally, if not in all cases, a *pattern* of simultaneously occurring responses. Accordingly, when one speaks of a series, or of any fragment thereof, one must not

forget that it is a pattern of many similar activities. With this point in mind, it will be profitable to discuss still some other facts of behavior revealed by well-trained organisms.

To refer again to Fig. 4, either one of the rhythms there present may occur without the others, as the presence of only the 5-rhythm in the initial part of the series indicates; but, when the 5-, 7-, and 11-rhythms occur simultaneously, as is the case later in the series, accents seem at first sight to occur in a lawless or haphazard fashion. After these rhythms occur simultaneously many times, however, they appear, as a rule, to occur together hereafter, i. e., in later tests. It is frequently the case that they occur together, but it is sometimes only an appearance. The fact that every fifth, seventh, and eleventh element is accentuated does not necessarily mean that the original three differently rhythmized series are present at the same time. For instance, that series which was rhythmized by having its every fifth element accentuated, may be entirely absent; but it may appear to be present merely because certain of the constituent parts of its accents have been transferred to numerically corresponding elements of other series present in the amalgamation of activities. *A single one or several of the activities of brief duration which were, in the training, associated with the fifth element for instance,* and caused it to indicate in the record a greater expenditure of muscular energy than its neighboring elements, which were not affected in the training, *became associated with and were accordingly later conditioned by the numerically corresponding element of at least one other series that previously occurred in the amalgamation of rhythms.* The revelation of this mutual transference of constituent parts of accents of one series to numerically corresponding elements of entirely different series, was the result of the application of intentionally chosen discrimination activities in experiments designed to determine the pattern-like nature of a given series, which was for various reasons supposed to be an amalgamation of a number of qualitatively very similar or allied responses.

Dominant and subordinate groups can often be detected in each pattern response: Because of the above discussed mutual transference — which means the 'adoption' by the elements of the different simultaneously occurring series of some of the constituent parts of accents—there is eventually after long and persistent training, no indication of dominance or subordinacy of any one rhythm of the amalgamation. At the first few noticeable cases of temporally superimposed rhythms, a single one of them is generally dominant in expression over

the others; they may be alternately dominant and subordinate, but they are as a rule not equally distinct at the same time. The only criterion of dominance and subordinacy of the rhythms, is the relative strengths of their accents; that rhythm with the most pronounced accents is the dominant one. *When the 5- is the dominant and the 7- the subordinate rhythm, this merely means that the number of 5-rhythms in the amalgamation exceeds that of the 7-rhythms. If only a single 5-rhythm should be present, every fifth element of the series of movements would condition fewer of the extra activities to increase its strength than would be the case if many 5-rhythms were occurring simultaneously.* This is equivalent to saying the simpler a movement is the fewer activities it conditions; or, the compound movements condition the greater number of extra responses. Let us say that when a single 5-rhythm is present, every fifth element conditions five brief responses, and that when ten 5-rhythms occur simultaneously, every fifth element conditions ten times as many or fifty brief responses as the contituent parts of any accent. It is very likely not the case that the simpler element conditions exactly one-tenth the number of brief responses induced by the specified compounded movement; but the only point which I wish here to emphasize is that the more complex element should condition the greater number of extra responses, and should accordingly indicate, for this if for no other reason, the greater expenditure of muscular energy.

As a conclusion of the preceding paragraph, the general statement may be made that *dominance vs. subordinacy of an activity means the occurrence of many vs. relatively few allied or qualitatively very similar responses.* The term allied responses refers to those which are so similar qualitatively to one another that they can easily occur simultaneously.[6] It is not necessary that the discontinuous responses in question be rhythmized; my only purpose in rhythmizing any series of movements was to train the organism in such a systematic fashion that I might be enabled to analyze a given amalgamation of activities into its various components.

The natural tempo of a group changes to match that of a simultaneously occurring and dominant group: A careful study of systematically trained animals reveals the fact that simultaneously with the occurrence of a larger number of responses, which are allied to the extent that they have the same characteristic tempo, a relatively small number of responses of one

[6] I mean to use the term 'allied responses' strictly in the traditional sense.

or more other characteristic tempos, can occur; but, in such a case, the tempos of the latter are modified to match that of the larger number of allied responses. *The tempo of movement of the smaller number of responses is determined by that of the larger number of allied responses of the amalgamation.* This means that *although the tempo of a dominant response is extremely constant and difficult to alter without interrupting the series entirely, as a subordinate response its tempo is easily altered.* The fact that in many cases two sets of non-allied responses occur simultaneously, can be clearly demonstrated by the use of properly chosen discrimination activities. For example, the two groups of Fig. 2 were caused to occur simultaneously[7] by presenting simultaneously appropriate stimuli for the initial elements of those groups. There occurred at such times a temporal correspondence of the elements as was shown by the fact that when the group of the slower tempo was dominant, a discrimination activity — a grunt-like noise uttered by the cockatoo — which was previously associated with only the final element of the other group, was executed. This can mean only that the relatively few responses which formed the subordinate group of the amalgamation, sufficed to condition the vocal response. Experiments with the internal accents of quantitatively the same and different groups yielded analogous results.[8]

We may speak of the thus altered tempo of the subordinate group as a *forced tempo.* And the fact of the forced tempo enables us to better understand why it is that an organism which is trained to beat with a given bodily member, for example a 5-rhythm in a given tempo, is later capable of beating numerically the same rhythm in all other tempos and with all other bodily members. Stimuli which are presented while a series is in progress and cause given elements of the dominant response to be modified, affect similarly the numerically corresponding elements of the one or more subordinate responses of the amalgamation. The subordinate responses of this amalgamation will later occur as dominant ones in their ordinary or characteristic tempos, and will show the numerical modifications that were brought about while they were subordinate in the amalgamation of activities which was affected by the training.

An established pattern tends to shatter: Our view of the

[7] This experiment was performed many months after Fig. 2 was made.

[8] Such an experiment with the same cockatoo, I reported in an earlier article, Ueber einfache Bewegungsinstinkte und deren künstliche Beeinflussung, *Zeit. f. Sinnesphysiol;* 1915, S. 287-288.

subordinacy and dominance of groups enables us to understand immediately the fact that while a dominant group of relatively short duration does not recur as such until a pause of several seconds has elapsed, it *apparently* recurs immediately as a subordinate group. The fact seems to be that the large number of allied responses which occurred together as a dominant group at the time of the training, do not become so permanently associated in the simultaneous order that they must always occur together. A few of these which were modified in the training, may later occur in the absence of the majority, and accordingly leave the impression on an observer that the dominant group may occur immediately as a subordinate one. This may happen in the case of long rhythmized series; in which case, we speak of alternately dominant and subordinate rhythms.[9]

B. Grasping Responses

As is indicated by the following investigations of the grasping activities of crayfishes, turtles, babies, and birds, these responses also are subject to essentially the same laws of behavior as those obviously discontinuous responses already discussed. Grasping responses too, are discontinuous.

The crayfish: The young crayfish grasps with its feet and clings to the chitinous hairs which fringe the swimmerets of its mother. The large claws or chelipeds are the principal grasping organs; and I shall consider these to the exclusion of the walking legs, the first two pairs of which are also grasping appendages. With a single cheliped the young crayfish can support, according to my rough estimations, from one to one hundred times its own weight; in fact, while supporting a heavy weight, the member sometimes snaps off at its base if left grasping the object for a short interval. For the reason that it is inconvenient to work with such a small and delicate animal as the young crayfish, I shall consider only the grasping activity of the adult. The adult, when agitated, grasps an object which stimulates the sensitive hairs of an open cheliped; but, if the object is a rigid one, it is very soon released. However, I have observed crayfishes to cling with a single cheliped to a soft watery weed or to a piece of flesh for an hour or so.

I did not find it agreeable to allow many of the larger-sized crayfishes to pinch my finger; but those large ones which had molted only shortly before, caused me no pain. I accordingly

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[9] For such alternately dominant and subordinate rhythms, see my article, Mechanische Rhythmen bei dem Menschen, *Zeit. f. Sinnesphysiol.*, 1916.

worked more extensively with these. I permitted a large soft-shelled animal to grasp my index finger just a short distance behind the root of the nail; and I noticed that during this act of long duration, the animal pressed unusually hard with an extreme regularity in the tempo of 0.73 seconds. This was exactly my pulse rate. Apparently every time my finger became enlarged slightly with blood, the crayfish was thereby stimulated to pinch harder. The behavior of the animal at each of these accentuations within the grasping activity, showed clearly that it exerted its entire body at these intervals. Many other crayfishes, however, made such exertions at quite irregular intervals; they did not seem capable of pinching more strongly in the rapid tempo of 0.73 seconds. In such cases, I introduced a regularity of the accents by squeezing my wrist until I had counted each time ten pulse beats. Every time I released my wrist, the crayfish in pinching more strongly folded its abdomen or tail more tightly, moved its walking feet in various directions, and attempted — as it seemed — to reach my finger with the other cheliped. After I had thus stimulated a crayfish at every tenth pulse beat for a large number of times, I observed that when I purposely failed to release the wrist at the tenth beat, the crayfish behaved as though I had done so; it pinched harder and at the same time executed the other movements mentioned. By this means, I rhythmized an apparently continuous response; for when I allowed a thus trained animal to grasp a piece of frog, turtle, snake, snail meat, or even a piece of watery weed, it responded similarly as when my finger was the object grasped. When I used fresh frog, turtle, or snake meat, I found it much easier to observe the periodic responses of the crayfish because each of the strong exertions of the animal frequently called forth a decided contraction of the muscles that were being pinched.

Pauses between experiments necessary to conserve the subject: My experiences with the crayfishes, lobsters, and crabs have shown me that if one works unceasingly with one of these animals, it eventually becomes a worthless subject; one must make pauses at short intervals, giving the animal a long rest at each time—otherwise it will soon cease to grasp at all. In order to work extensively with a single animal, I allowed it to grasp for a period of not over thirty seconds before the long pause was made. My attempt to thus conserve a given subject for a large number of experiments, gave rise to the experiment of the following paragraph.

In order to bring about the pause, I did not pull the animal

loose from the object which it was grasping but dipped its tail in water, touched it on the ventral surface of the abdomen, or suddenly blew my breath onto its body. I caused an animal to release my finger at the thirtieth pulse beat. After many such ordeals, I found that the animal released my finger at this point in the absence of the interrupting stimulus. By this means, I accordingly isolated a fragment from the response of long duration. It is interesting that in certain cases of well-trained animals, this isolated fragment was rhythmized; it terminated just as the third unitary group was completed. To be sure, the elements of the unitary groups could not be perceived as a number of beats; but they were present because the grasping member was exerting itself during the while and an extra response, which was conditioned at one point of the series, was not conditioned at any other point of that series. Three different accents occurred at very definite points of the series. A demonstration that these were at least not in all cases the same extra responses repeated at regular intervals, is that the third one inhibited the grasping response completely while the others merely accentuated certain elements of it. *In the sense that there is a qualitative change from point to point of the grasping response, the activity can be said to be a discontinuous one.* As was demonstrated in these experiments, pronounced beats can be inserted along the response to make it resemble the obviously discontinuous ones which were considered earlier in the paper.

It is really a very easy matter to train a crayfish to release objects very soon after they are grasped. I found this to be so very easy that I had to use a number of precautions in order to conserve the subjects for such investigation as those above reported. Instead of saying that I taught an animal to release an object immediately after grasping it, I should say that *I broke the activities of long duration up into fagments of such short duration that the animal supported its weight for only a very short time.*

The turtle: Experiments with 'snapping-turtles' revealed essentially the same facts. I observed a large turtle while it dug with its hind feet in the sandy earth on the bank of a stream. After the cavity was finished and after it had deposited eighteen eggs in it, I appoached the animal. It lay as if dead until I pulled its tail, after which it hissed and snapped viciously at me whenever I made a slight movement. When I jumped behind it, the turtle snapped at me before taking time to turn the body. At such times the head hit the back of the shell with such force that it quickly rebounded against the

sand in front of the animal. I allowed the turtle to bite a piece of leather, which was my belt. It clung so tightly to the belt that I could sling the heavy animal round and round me without causing it to release its hold. I fastened the belt to the branch of a tree by hooking the buckle over a broken limb, and left the turtle hanging. Shortly after I hid behind a thicket of bushes, the turtle released the belt and fell. After I had done this about two dozen times, the turtle had apparently lost its ability to grasp the belt for any great length of time; for in my presence, it thereafter released the belt after a very short interval of grasping. But the ability was not completely lost; for when I set the animal swinging, pulled its tail, or 'jabbed' it on the soft parts at regular intervals, it clung to the belt for a long time. Moreover, after I had removed all its viscera, thus leaving the mere hull of shell and musculature, the turtle also clung to the belt for a considerable time.

At another time I found two turtles copulating. Because the male seemed to be the more vicious of the two, after they were separated. I worked primarily with it. By jumping at it, by striking at it with my hand, or by blowing in its face, I could induce it to snap at me. In some mud I found a straight tree branch which was decayed and soft on the outside but solid in the central region. I enticed the turtle to bite this. The animal supported its weight for seveal minutes at a time when I agitated it during the while. I cut a tin can so that it was cup-shaped, cut a round hole in the bottom, and through this I passed the end of the branch which I then allowed the turtle to bite. After the turtle had supported its weight for a period of twenty seconds, I let the can fall down the stick, thus covering the entire head of the turtle. On such occasions, the thus hooded animal frequently responded by moving its feet and tail rapidly in various directions, and in a few cases it released the stick. I prepared another can which was so light and shallow that it, when dropped down the stick, generally called forth the movements of the feet without causing the animal to lose its hold on the stick. I then dropped this can at intervals of five seconds, thus causing the distinct movements of the feet and tail at five-second intervals. After I had repeated this ordeal about six hours, the can became a superfluous stimulus to call forth the feet and tail movements; that is, the turtle responded at approximately five-second intervals as if to the falling can, but in the absence of this stimulus. The grasping activity which, in the case of the agitated turtle, was of very long duration, became rhythmized.

I next built a fire and heated the larger of the two cans. After the animal had supported its weight for about fifteen

seconds, I slipped the heated can over the opposite end of the stick and allowed it to fall down upon the turtle's head at the end of the period of twenty seconds. The turtle released the stick almost immediately. After I did this a large number of times, the turtle generally fell at the end of the twenty-second interval, independently of whether the can was dropped or not. The errors which occurred were generally slight over-estimations of the twenty-second period. By this training method, I isolated a relatively short fragment of definite duration from the response of long duration. What is more, the segment which was thus isolated, was rhythmized; for the turtle, because of its previous training with the smaller can, moved its feet and tail in approximately five-second intervals while the segment was in progress.

I worked with still other turtles in the same way and achieved similar results. I found, however, that it was not necessary to heat the can; for when I filled it with tobacco smoke, which lingered in the over-turned can, and allowed it to fall down the stick the animals released the objects as readily as when the can was heated.

In the case of the turtles, it was necessary to make long pauses occasionally; otherwise they, like the crayfishes, would cease to grasp or at least not support their weight a sufficiently long time for my purposes.

The human being: The grasping activity of the human being seems to be essentially the same as that of the crayfishes or turtle. The newly born child grasps and clings to an object which stimulates the palm of its hand. If the object is light, the child throws it back and forth without releasing it; which fact indicates the analytic nature of the response. But if it cannot move the object, as when the arm is stretched in supporting the body, the act of long duration seems to be a continuous one. Any stimulus which interferes so seriously with this response that the hand releases the object, causes the child to become active in some new way. This new or extra activity is the immediate cause of the interruption of the responses of long duration; it isolates a fragment from the response in question and is later conditioned by the latter part of the fragment which it isolated. In the course of time, the grasping response of the child, like that of the crayfish or turtle, becomes broken up into so many relatively short fragments that the child almost invariably releases the object after a very short time; and we can then say that the grasping activity has degenerated. The ability to grasp and support the weight of the body is, however, not lost; for even the

adult can do so when properly stimulated. I shall suppose that he can support his weight for a considerable time when appropriate stimuli are presented to call forth stimultaneously and successively an unusually large number of the isolated fragments. It seems plausible that the most adequate stimuli for this purpose are some of the hormones—secretions of the ductless glands of the body—which are thrown into the blood under conditions of excitement. It is perhaps for this reason that the crayfish, turtle, or human grasps for an unusually long time when agitated.[10]

The grasping activity is only one of great numbers of responses of long duration which become broken up into relatively short fragments during the period of early infancy. The disintegration seems to occur to some extent before birth, as is indicated by the fact that some newly born infants either do not grasp strongly or soon release the object grasped unless they are in a state of emotion at the time.[11] Human infants are, as a rule, subjected to various sorts of treatment by adults; and, as a rule, the environment of one child is otherwise rarely identical with that of another. This means that human infants are trained in many different ways. They receive such unusual treatment that we should expect the idiosyncrasies of the human to be much greater than in the case of almost any other animal species. Even the children of a single family are not subjected to the same training; the various responses of long duration are in one case broken up into fragments which are re-combined with the allied and non-allied groups to form different activity compounds from those of a brother or sister. If all the children of a family were born in a litter and subjected to the same environmental conditions during the early period of infancy, as are young bees, ants, wasps, or birds in a nest, we should expect the activity compounds manifested by the individuals later in life to be practically the same.

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[10] This theory is worked out in somewhat greater detail in my article on Relevant and Irrelevant Speech Instincts and Habits, *Psychol. Rev.*, Oct. 1917. The subject of discussion there was the fact that stuttering and stammering activities are unusually prevalent when the individual is in a state of excitement.

[11] See John B. Watson and J. J. B. Morgan, Emotional Reactions and Psychological Experiments, *Amer. Jour. of Psychol.*, XXVIII, 1917, pp. 170-171. "In many cases we find that the child either cannot at first support its full weight with either right or left hand, or if so only for an instant. If, however, we first produce a state of rage in the infant by hampering its movements we rarely fail to get it to support its full weight for a considerable time.

C CONCLUSIION

Throughout the previous discussions, I have given reasons for supposing that all muscular responses of long duration are discontinuous in the sense that the nervous correlates of a limited portion of such a response are not exactly identical with those of any other portion of the same response. Assuming then the discontinuity of all the muscular responses or the persistaltic-like nature of responses in general, and speaking only of the behavior correlates of the structures that function,[12] the following law of induction can be stated: *The initial element of the innately associated series of elements of the responses of long duration conditions or induces its qualitatively most similar element; this in turn induces its most similar element which has not occurred immediately before, and so on until the qualitatively most dissimilar element to the initial one is induced.* This law is essentially the same as a law of color induction which I stated elsewhere[13] as follows: *In successive and simultaneous color induction, any color induces first itself and last of all its antagonistic color.*. The only difference between the two statements of the same law of behavior is that in the one case, emphasis is laid upon the qualitative natures of the muscular movements which succeed one another, while in the other field of behavior, the succession of psychical states only are brought into consideration.

If all the quantitive expressions were eliminated from the previous discussion of obviously discontinuous responses, still more completely than was done in the case of the grasping activities, and if the term 'pattern of visual responses' were consistently substituted in the *proper* places for the term 'pattern of muscular responses' wherever the latter is written or merely implied, that discussion would be thereby converted into a fairly complete theory of visual instincts and habits supported by the facts of vision. Special caution should be used, however, to make these substitutions at the *proper* places; for in a discussion of visual responses, certain muscular responses should be taken into consideration. These are the ones which carry the body through space or merely cause the fixating organism to change its point of fixation, thus causing the retinas to be stimulated in new ways while any given visual response is in progress. These extra muscular movements are responsible for the isolation of fragments

[12] I do not intend to present a physiological theory of induction at this point of the paper; and shall therefore not formulate a strictly physiological law of induction at this time.

[13] Positive After-Images of Long Duration, Amer. Jour. of Psychol., 1916, XXVII, p. 332.

from the visual responses of long duration and the consequent shortening of the original visual series; they become associated with, and are later conditioned by the fragments which they caused to be dissociated from the longer visual series. It is primarily because of these particular muscular movements, which have previously modified the visual responses, that perfect fixation is such an extremely difficult task.

We should expect that if kinæsthetic and visual responses are governed by the same laws of behavior, these laws should be likewise applicable to cutaneous, olfactory, gustatory, and auditory responses. My researches indicate very strongly that this is the case; and, in closing, I wish to express my conviction that the system of thinking brought out in this article is especially significant for a theory of auditory instincts and habits.